ADSORPTION OF MOISTURE FROM THE MOIST AIR BY THE SOILS

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(*Received for publication, September 10, 1940*)

ABSTRACT. A method has been devised to study the adsorption of moisture from the moist air by the soils inside the laboratory. Various factors which influence such adsorption have been studied and the following results are obtained :--

(1) The adsorption of moisture from the moist air by the soils increases with the increase of range of humidity. It is comparatively higher in the beginning than in the end. (2) The rate of adsorption of moisture from the moist air increases with the increase of thickness of of the layer of the soil up to a certain limit depending upon the quality of the soil. This rapidly decreases with the depth of the layer from the upper exposed surface. (3) Adsorption increases with the time but the rate of adsorption is high in the beginning and regularly slackens on as the time elapses. It is proportional to the logarithm of the time exposure. (4) Adsorption decreases with the size of the particles or groups of particles (clods) and their proportion in the soil. (5) Adsorption depends upon the physical and chemical constituents of the soil.

The discussion of each factor is given in detail.

INTRODUCTION

Much work has already been done on the soil moisture in the past. In 1934, L. A. Ramdas and M. S. Kati [1] showed that the phenomenon of the evaporation of moisture from a soil surface containing only hygroscopic water and the reverse phenomenon during night exert a controlling influence on the distribution of moisture with height in the air layers and that during the evaporating regime the pressure of the water vapour decreases with height, whereas during the adsorbing regime the pressure of the water vapour increases with height. In 1936, they [2] studied the diurnal variations in the moisture content by two-hourly measurements with representative soils from different parts of the country, the soils being exposed under identical conditions in the Agricultural Meteorological Observatory at Poona. The moisture content of the surface layers of the soil in the bare ground of the same observatory were also measured. Experiments on the adsorption of moisture by dry soils and measurements of various related physical properties of typical soils were also made. In all these cases, the soils have been used as they occur, *i.e.*, without separating them into their components by mechanical or chemical analysis, and the meteorological aspect has been kept in the fore-front.

In order to study the above, the above-mentioned workers and others used such methods where the samples of the soils were kept either outside in the open field or inside the louvered screen. In both these methods the experiments were intended to reveal the phenomenon of adsorption and desorption of moisture under actual field conditions.

But these methods, from the point of view of a physicist, cannot be used for the general study of adsorption of moisture from the moist air by the soils, as in both of these methods, the variation of humidity is at the mercy of the weather and observations have to be extended over a long period, otherwise a great range of variation of humidity is not possible. The humidity cannot be kept constant for any length of time. Besides there is possibility of dust or fine particles of dust which are more or less always hanging in the air, depositing on the samples of the soils.

In order to avoid these difficulties, the author [3] has devised a simple apparatus by which the humidity can be varied within a great range, even from 0 to 100% quite easily and it can, if desired, be kept constant for any length of time. The possibility of the dust particles depositing on the samples of the soils is completely avoided.

With this apparatus, the adsorption of moisture from the moist air by the soils and the exchange of moisture between the earth and the air has been studied *in this laboratory*. The effects of the humidity of the air, the thickness of the layer of the soil, the time for which the soils are exposed to the moist air, the size of the particles of the soil, the quantity of the clods in the soil, and the physical and chemical constituents of the soils on the rate of adsorption of moisture by the soils has been studied and the relations which exist between them have been traced out in the following lines.

THE APPARATUS

In this apparatus, the use of Professor J. B. Seth's method [4] for production of a current of dry or moist air of any desired percentage of humidity has been used. The currents of dry or moist air of suitable strength are sent into a chamber and any constant humidity is regulated. A small quantity of the soil in a dish is kept inside it at almost normal pressure. After keeping it there for some definite time, it is removed and weighed and its hygroscopic or adsorption power is calculated. The pressure inside it is kept constant and is measured with a mercury manometer. This chamber is connected with another similar chamber which in turn is connected with an exhausting pump or an aspirator. Thus the effect of rapid flow of air due to the exhausting pump or any other devise is avoided. In order to record the humidity, a well-tested and calibrated hair hygrometer is kept hanging in the first chamber and for its varification a wet and dry blub hygrometer is kept in the second chamber.

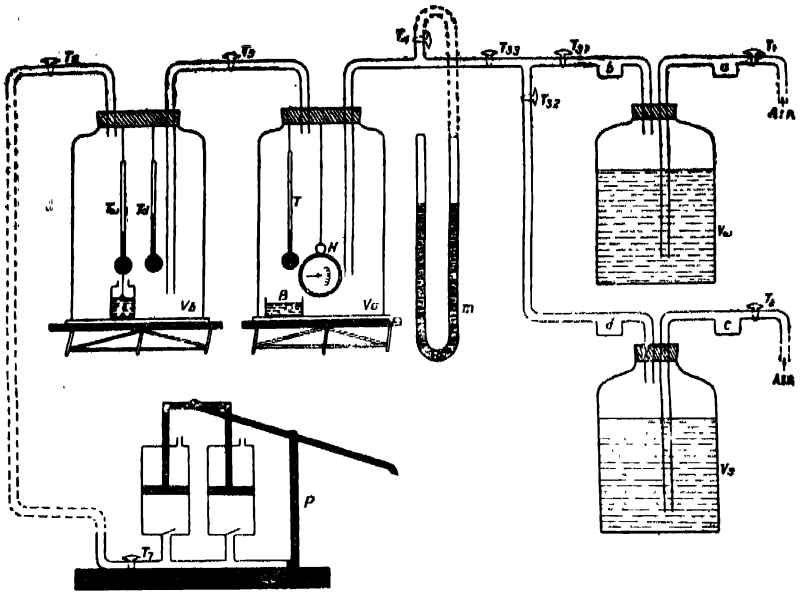

FIGURE 1

Construction :—The details of the apparatus are shown in fig. 1 (line sketch), where V_w and V_s are two-litre capacity bottles containing pure water and strong sulphuric acid respectively, m a mercury manometer, and P a double-action exhausting pump. V_a and V_b are two glass chambers without bottoms. At their bottoms are placed two separate glass plates with rubber discs on them which make them fairly air-tight. There are two tubes opening inside the vessel V_a, one being an inlet from the source for a current of dry or wet air and the other an outlet for the enclosed air to the exhausting pump or an aspirator. T_d and T_w are dry and wet bulb thermometers. a, b, c and d are four glass traps on both sides of the liquid bottles in order to avoid the flow of the liquids on either side. T_1, T_2, T_3, T_4, T_5, T_6, and T_7 are stop-cocks fitted at various places to control the current of air and are used according to the needs.

Working :—The double-action air pump is worked so as to create a low pressure in chamber V_b. This causes a current of air to flow from outside through any of the liquids in the vessels V_w and V_s. This current of air passes through the chamber V_a after affecting the pressure of the mercury manometer on its way and fills the low-pressure space in the chamber V_b. If an aspirator is used instead of the exhausting pump, a regular current goes on flowing in from outside to the chamber V_b and also affects the humidity of the air inside the chamber V_a. If humidity is to be decreased, T_2 is opened and T_1 is closed, or if humidity is to be increased, T_2 is closed and T_1 is opened. In the former case the current of air while bubbling through sulphuric acid is devoid of its moisture and lowers the % humidity, while in the latter case the air when bubbling through water carries moisture with it and increases the humidity. If a current of air is regulated any constant humidity for any length of time can be

arranged inside the chambers. Having known the weight of the empty dish B and of the soil in it before placing it inside the chamber and after exposure to the new humidity for any definite period of time, the increase or decrease in weight of the soil for the corresponding variation of humidity can be known. The dish can be taken out of the chamber by removing the bottom plate from below.

OBSERVATIONS

With a few samples of soil taken from the Botanical Garden of this college, several observations have been taken. The effects of various factors which influence the adsorption of moisture from the moist air by the soils have been studied with these samples and a few sets of observations are given below :—

1. HUMIDITY OF THE SURROUNDING AIR

For this purpose a flat-bottomed dish having cross-sectional area 10·36 sq. cms. was filled with a fine soil having layer of thickness 20·6 mm. and was exposed to the moist air of various humidities for a constant period of time 24 hours. The increase in weight for the corresponding increase in humidity was determined in each case. Several sets of observations were recorded and a typical set of observations is given below.

TABLE I

Kind of soil : fine

No.	Initial wt. in gm.	Final wt. in gm.	Initial % Humidity	Final % Humidity	Increase in % Humidity	Increase in wt in gm.
1	61·7125	61·7635	18	22	4	0·0510
2	,,	61·8020	,,	28	10	0·0895
3	,,	61·8955	,,	42	24	0·1832
4	,,	61·9600	,,	55	37	0·2475
5	,,	61·9750	,,	59	41	0·2625
6	,,	61·9945	,,	64	46	0·2820
7	,,	62·0005	,,	80	62	0·2880

The above observations are also shown by a curve in fig. 2 which indicates the behaviour of the fine soil with the increase of humidity of the surrounding air.

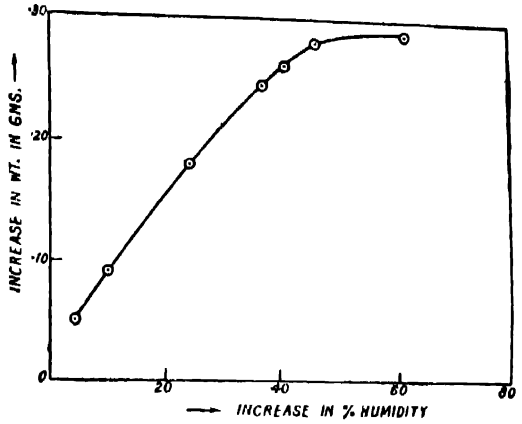

FIGURE 2

Some sets of observations were recorded with the sandy soil which contained about 95% of pure sand. The surface area exposed to the moist air, the thickness of the layer of soil and the time ofexposure were kept the same as in Table I. A set of such observations is recorded below :

TABLE II

Kind of soil : sand

No.	Initial wt. in gms.	Final wt. in gms.	Initial % Humidity	Final % Humidity	Increase in % Humidity	Increase in wt. in gm.
1	82·9550	82·9560	20	26	6	0·0010
2	,,	82·9580	20	28	8	0·0030
3	,,	82·9635	24	36	12	0·0085
4	,,	82·9660	20	37	17	0·0110
5	,,	82·9815	20	55	35	0·0265
6	,,	82·9820	20	64	44	0·0270

The above results are also shown by a curve in fig. 3 which shows the behaviour of the sandy soil with the increase of humidity of the surrounding air. This soil being almost a sand has very little power of adsorption of moisture from the moist air, however for a longer period it may be kept exposed to it.

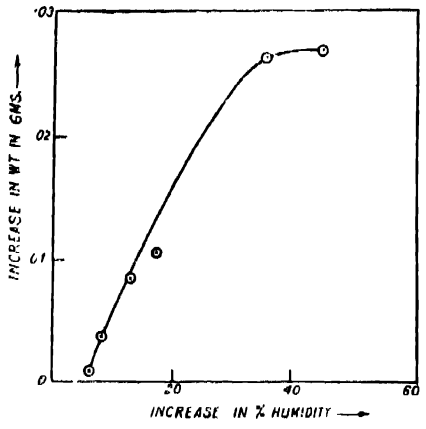

FIGURE 3

Both the above-mentioned curves are of the same shape and indicate that the adsorption of moisture from the moist air by any kind of soil increases with the increase of relative humidity of the surrounding air. The rate of increase in weight, *i.e.*, the adsorption of moisture is comparatively high in the beginning and slow later on. Thus it is evident that the rate of adsorption of moisture slowly decreases with the increase of relative humidity.

2. THICKNESS OF THE LAYER OF SOIL

The effect of the thickness of the layer of the soil was studied by using the same flat-bottomed dish of glass having cross-sectional area 10·36 sq. cm. Time exposure (two hours) and the range of variation of relative humidity (60 to 80%) were kept constant and the thickness of the layer of the soil was varied. With this arrangement several observations were recorded. A set of observations is given below in table III.

TABLE III

Kind of soil : fine

No.	Initial wt. in gms.	Final wt. in gms.	Thickness of layer of soil in mm.	Increase in wt. in gm.
1	8·3050	8·3370	3·0 mm.	0·0320
2	21·8630	21·9310	7·2 ,,	0·0680
3	35·4235	35·5010	11·8 ,,	0·0775
4	61·9750	62·0550	20·6 ,,	0·0800
5	86·0755	86·1660	28·6 ,,	0·0905
6	133·0685	133·1605	44·3 ,,	0·0920

The above results are also shown by a curve in fig. 4 which represents the variation in adsorption with the thickness of the layer of the soil. The amount of moisture adsorbed by any kind of soil increases with the thickness of the layer of the soil up to a certain limit which varies according to the quality of the soil.

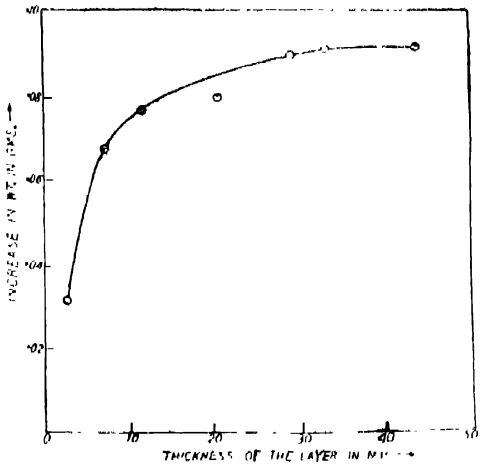

FIGURE 4

The upper layers adsorb much more moisture than the lower layers of the same thickness. The rate of adsorption rapidly goes on decreasing with the depth of the layer from the upper surface which is exposed to the moist air directly, and it is self-evident from the curve itself. The following data is deduced from the same curve :

The increase in weight for 3 to 10 mm. layer is 0·042 gm.
,, ,, ,, ,, 10 to 20 mm. layer ,, 0·011 gm.
,, ,, ,, ,, 20 to 30 mm. layer ,, 0·005 gm.
,, ,, ,, ,, 30 to 40 mm. layer ,, 0·0015 gm.

The layer which is at a depth of 3 mm. from the directly exposed surface and 7 mm. thick adsorbs 0·042 gm. of moisture from the moist air while a layer which is at a depth of 10 mm. from the exposed surface and 10 mm. thick adsorbs only 0·011 gm. Similarly a layer which is at a depth of 20 mm. and 10 mm. thick adsorbes 0·005 gms. and a layer which is at a depth of 30 mm. and 10 mm. thick adsorbs only about 0·0015 gm. which is negligible. Thus it is quite evident that beyond a depth of about 4 mm. almost no effect of adsorption is noticeable. It is merely the superficial layer which can adsorb the moisture from the moist air and very low layers remain quite unaffected.

3. TIME

The effect of time on adsorption of moisture from the moist air by soils was studied with the same apparatus. The same flat-bottomed dish of glass, having

crosss-sectional area 10·36 sq. cm. was used. The range of variation of humidity (50 to 65%) and thickness of the layer of fine soil (44·3 mm.) were kept constant, while the time period for which a sample of soil was exposed to the moist air was varied. Several sets of observations were recorded and one of those sets is given below :—

TABLE IV

Kind of soil : fine

No.	Initial wt. in gm.	Final wt. in gm.	Time of exposure in minutes	Logarithm of time	Increase in wt. in gm.
1	132·7625	132·8205	12 min.	1·0792	0·0580
2	,,	132·8285	18 ,,	1·2553	0·0660
3	,,	132·8375	30 ,,	1·4771	0·0750
4	,,	132·8695	66 ,,	1·8195	0·1070
5	,,	132·8745	120 ,,	2·0792	0·1120
6	,,	132·8815	180 ,,	2·2553	0·1190

A curve (fig. 5*a*) has been drawn showing the relation between the increase in weight of the soil due to adsorption of moisture from the moist air and the time in minutes. This indicates that the amount of adsorption increases with time but the process of adsorption is rapid in the initial stages and slackens on as the time elapses. In other words the rate of adsorption decreases with time.

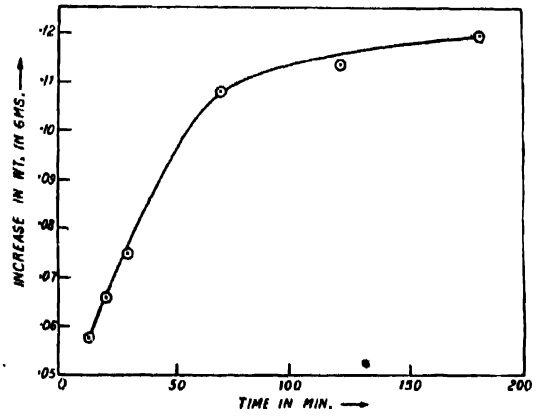

FIGURE 5(*a*)

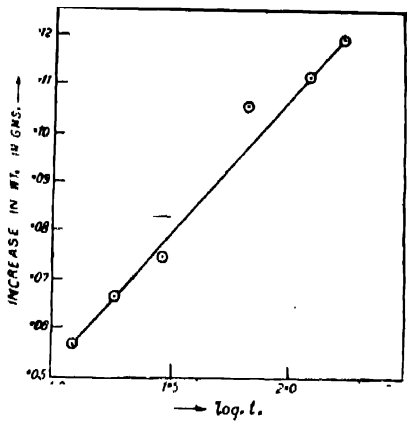

FIGURE 5(*b*)

The study of the relation between these two variable factors shows that if a curve (fig. 5*b*) be drawn between the logarithm of time and increase in weight of the soil a straight line is obtained, which leads to the conclusion that the amount of moisture adsorbed from the moist air by the soils is directly pro-

portional to the logarithm of time for which the soil sample is exposed to the moist air. Thus the relation is logarithmic.

4. SIZE OF THE PARTICLES

In order to study the effect of the size of the particles and groups of particles, *i.e.*, clods of the soil on the adsorption of moisture, the same flat-bottomed dish was used. The range of variation of humidity (80 to 90%) and the thickness of the layer of the soil (16 mm.) were kept constant. Two samples of the soil were used, one being in its natural condition having a large number of thick particles of soil and clods and the other being a finely powdered soil obtained from the natural soil by grinding it. The following sets of observations were recorded :

TABLE V

No.	Kind of soil	Initial wt. in gm.	Final wt. in gm	Time of exposure	Increase in wt. in gm.
1	Finely powdered	81·9825	82·0025	60 min	0·0200
	Natural	79·3390	79·3450	,,	0·0060
2	Finely powdered	81·9825	82·0735	24 hours	0·0910
	Natural	79·3390	79·3980	,,	0·0590
3	Finely powdered	81·9825	82·0695	20 hours	0·0870
	Natural	79·3390	79·3900	,,	0·0510

The above observations show that the adsorption is much smaller in natural soil than in finely powdered soil. In other words, the amount of moisture adsorbed from the moist air decreases with the increase of size of the particles and groups of particles (clods) and also their proportion in the soil.

The reasons for less adsorption in the natural soil possibly appear to be that (*i*) less surface is exposed to the moist air when there are large-sized particles and clods in the soil and (*ii*) the capillary action is much smaller in this case as the interspaces between the particles become large due to large size of the particles.

5. CHEMICAL AND PHYSICAL CONSTITUENTS

The comparison of observations in tables I and II shows that the adsorption of moisture from the moist air is much more in fine clay soil than in the sandy soil. If the quantity of sand in any soil increases, the amount of adsorption decreases in the same ratio. The rate of adsorption of moisture from the moist air also depends on the chemical constituents of the soil.

RESULTS

The following results have been concluded from the study of various factors influencing adsorption of moisture from the moist air by the soils :

1. The adsorption of moisture from the moist air by the soils increases with the increase of range of humidity. It is comparatively higher in the beginning than in the end.

2. The rate of adsorption of moisture from the moist air increases with the increase of thickness of the layer of the soil up to a certain limit depending upon the quality of soil. This rapidly decreases with the depth of the layer from the upper exposed surface.

3. Adsorption increases with time but the rate of adsorption is high in the beginning and regularly slackens on as the time elapses. It is proportional to the logarithm of the time of exposure.

4. Adsorption decreases with the size of the particles or groups of particles (clods) and their proportion in the soil.

5. Adsorption depends upon the physical and chemical constituents of the soil.

CONCLUSIONS

The above-mentioned results throw light on the work done in the past. The study of the comparison of hygroscopic property of the Patiala soil with other Indian soils and the effects of other influencing factors on them is in progress in this laboratory and shall be published in due course of time.

The author is indebted to His Highness's Government, Patiala, for providing facilities to carry out the above work in the Research Laboratory of the Mahendra College, Patiala. My grateful thanks are due to Dr. L. A. Ram Das, Agricultural Meteorologist of the India Meteorological Office, Poona, for providing me with some of his research papers and of various others for reference use only.

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